

Our Ref.: 51040.P005

APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

**Pipelined Deciphering Round Keys Generation**

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*"Express Mail" label number* EL605310337US

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## Pipelined Deciphering Round Keys Generation

### BACKGROUND OF THE INVENTION

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#### 1. Field of the Invention

The present invention relates to the field of ciphering and deciphering. More specifically, the present invention relates to line rate deciphering having special application in network traffic routing.

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#### 2. Background Information

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With advances in integrated circuit, microprocessor, networking and communication technologies, increasing number of devices, in particular, digital computing devices, are being networked together. Devices are often first coupled to a local area network, such as an Ethernet based office/home network. In turn, the local area networks are interconnected together through wide area networks, such as ATM networks, Frame Relays, and the like. Of particular notoriety is the TCP/IP based global inter-networks, Internet.

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As a result of this trend of increased connectivity, increasing number of applications that are network dependent are being deployed. Examples of these network dependent applications include but are not limited to, email, net based telephony, world wide web and various types of e-commerce. Successes of many of these content/service providers as well as commerce sites depend on high speed delivery of a large volume of data.

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At the same time, with increased concern over privacy and security, increasing amount of data are being transferred in a ciphered basis. As a result, successes of the content/service providers as well as commerce sites are also

dependent on the routing devices, as well as the servers and client devices being able to cipher and decipher data at a very high rate.

The fundamentals of ciphering and deciphering are well known in the art. Typically, a plain text is ciphered using a ciphering "master" key. The ciphering is effectuated incrementally over a number of iterations, employing a number of corresponding ciphering round keys. The ciphering round keys are generated from the ciphering "master" key using a round function, with the first ciphering round key generated directly from the ciphering "master" key and thereafter, each subsequent ciphering round key, from the immediately preceding ciphering round key, the original "master" key plus one or more pseudo random factors or other algorithmic approaches. The ciphered text is deciphered by applying the ciphering round keys backward. In other words, the first deciphering round key is the last ciphering round key.

The emphasis under the prior art to-date typically has been on the robustness of ciphering, that is, ensuring it is difficult for any attacker to uncover the deciphering round keys. Generally, the "undetectability" of the ciphering/deciphering round keys are enhanced by increasing the pseudo randomness injected between successive rounds of ciphering. As a result, if a deciphering unit, or a unit responsible for providing the deciphering unit with the deciphering round keys, is required to generate the deciphering round keys (e.g. in symmetric ciphering/deciphering), the deciphering round keys are fully generated (by re-generating the ciphering round keys in the conventional forward manner), before deciphering can take place (applying the re-generated ciphering round keys in reverse order as deciphering round keys).

The prior art approach of having the deciphering round keys fully generated is inefficient. In addition to having to wait for the generation of the last ciphering round key before deciphering can take place, the amount of storage elements required to

generate and hold all the deciphering round keys could be significant, especially for deciphering/deciphering processes that employ long ciphering/deciphering round keys and/or great numbers of rounds. The delay in the start of deciphering and the large amount of storage required are especially problematic for high speed

5 applications that require high line rate deciphering for multiple data streams at the same time, such as high speed optical networking, where multiple network traffic flows often have to be deciphered substantially at the same time. The reason being, the desired high line rate deciphering typically means that all the deciphering has to be performed on-chip in parallel. However, the large memory requirement, and the  
10 resulting substantial IC real estate consumption render these prior art approaches less than desirable.

Thus, a more efficient approach to deciphering, in particular, deciphering round key generation is desired.

## 15 SUMMARY OF THE INVENTION

An apparatus is equipped with a deciphering round key generator to successively generate in real time at least a first and a second deciphering round  
20 key based on a deciphering key, and a deciphering unit coupled to the deciphering round key generator to successively employ the real time successively generated deciphering round keys to incrementally decipher a ciphered text. The deciphering round key generator at least generates the second deciphering round key in real time while the deciphering unit deciphers the ciphered text employing the real time  
25 generated first deciphering round key.

In one embodiment, the deciphering round key generator generates the second deciphering round key in real time by iteratively generating its data words

over a plurality of iterations. In one embodiment, the deciphering round key generator includes a first XOR function, and iteratively generates the data words of the second round key over a plurality of iterations by generating one data word each iteration, performing an XOR operation on a first and a second round key data word using the first XOR function.

In one embodiment, the first round key data word employed in each iteration is a first predecessor round key data word of the first plurality of round key data words of one deciphering master key length preceding the round key data word to be generated, and the second round key data word employed is a conditionally transformed version of a second predecessor round key data word immediately following the first predecessor round key data word (in terms of their orders of re-generation).

In one embodiment, the conditional transformation includes outputting the “immediately following” predecessor round key data word without further processing, or further processing it before outputting the “immediately following” predecessor round key data word as the transformed version. The further processing conditionally includes one or more of rotational shifting, inverse computation, substitution, or another XOR operation.

In one embodiment, the apparatus includes multiple ones of the deciphering round key generators, and multiple ones of the deciphering units, to generate multiple series of deciphering round keys in corresponding pipelined manner for deciphering multiple network traffic flows at the same time.

In one embodiment, the apparatus is disposed on a single integrated circuit.

#### BRIEF DESCRIPTION OF DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

**Figure 1** illustrates an overview of the present invention;

5        **Figure 2** illustrates the ciphering and deciphering units of **Fig. 1** in further detail, in accordance with one embodiment;

**Figures 3a-3b** illustrates the ciphering and deciphering round key generation units of **Fig. 2** in further detail, in accordance with one embodiment;

10       **Figure 4** illustrates the transformation unit of **Figs. 3a-3b** in further detail, in accordance with one embodiment;

**Figure 5** illustrates an example data organization for the constant values of **Fig. 4**, in accordance with one embodiment; and

15       **Figure 6** illustrates an example routing device incorporated with the deciphering teaching of the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

20       In the following description, various aspects of the present invention will be described. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some or all aspects of the present invention. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the present invention. However,  
25       it will also be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well known features are omitted or simplified in order not to obscure the present invention. Further, the

description repeatedly uses the phrase “in one embodiment”, which ordinarily does not refer to the same embodiment, although it may.

### Overview

5 Referring now to **Figure 1**, wherein an overview of the present invention is illustrated. As shown, data sender **102** and data receiver **104** are coupled to each other via communication link **107**, over which data sender **102** may send data, including data in ciphered form, to data receiver **104**. Data sender **102** is equipped with cipher function **106**. More importantly, data receiver **104** is equipped with  
10 decipher function **108** incorporated with the decipher teachings of the present invention. As will be described in more detail below, in accordance with the present invention, decipher function **108** incrementally deciphers a ciphered text received from data sender **102** employing a number of deciphering round keys advantageously generated in a pipelined manner on an as needed basis. The  
15 ciphered text is assumed to be generated by cipher **106** in an incremental manner, employing a number of ciphering round keys (which may also be generated in a pipelined manner). Cipher **106** includes in particular a transformation unit having a number of substitution boxes and complementary operational elements employed in the iterative generation of the ciphering round keys. A number of substitution values  
20 are stored in the substitution boxes. Decipher function **108** is accordingly equipped with a similar transformation unit having similar substitution boxes and related complementary operational elements. The substitution boxes also having similar or substantially the same substitution values, representing the same function, transforming the inverse of an input value, thereby enabling decipher function **108** to  
25 generate the deciphering round keys in the desired pipelined manner. As a result, the amount of delay before deciphering can start, as well as the amount of storage

required to hold the relevant deciphering round keys at any one point in time are advantageously reduced.

Except for the decipher teachings of the present invention incorporated in decipher function **108** of data receiver **104**, data sender **102**, data receiver **104** and communication link **107** are all intended to represent a broad range of data sending, data receiving and communication systems and/or components known in the art. Accordingly, except for the deciphering teachings incorporated, these elements will not be otherwise further described.

### Cipher and Decipher Functions

**Figure 2** illustrates cipher function **106** and decipher function **108** of **Figure 1** in further details, in accordance with one embodiment. As illustrated, cipher function **106** includes cipher round key generation unit **202** and encryption function **204** coupled to each other as shown. Cipher round key generation unit **202** is employed to successively generates a number of ciphering round keys in real time in a pipelined and as needed manner, based off provided ciphering “master” key K. Encryption function **204** is employed to incrementally encrypt or cipher plain text M, using the generated ciphering round keys as they are successively made available. More specifically, ciphering round key generation unit **202** generates the next ciphering round key required by encryption unit **204**, while encryption unit **204** is incrementally ciphering the plain text M or an partially ciphered text for another round using the previously generated ciphering round key. In other words, ciphering round key generation unit **202** generates the first ciphering round key based off the provided ciphering “master” key K, and provides the first generated ciphering round key to use to incrementally cipher plain text M. Thereafter, while encryption unit **204** incrementally ciphers plain text M for one round, ciphering round key generation unit **202** generates the next ciphering round key. Upon completion of the first ciphering



round, encryption unit **204** incrementally ciphers the partially ciphered text for another round, while ciphering round key generation unit **202** generates yet another next ciphering round key. The process continues until the required number of rounds have been performed, with ciphering round key generation unit **202** generating the “last” ciphering round key, and thereafter, encryption function **204** incrementally ciphers the partially ciphered text for one last round, producing the ciphered text C.

Ciphering round key generator **202** includes in particular certain transformation means employed in the pipelined process of the present invention for pipelined generation of the ciphering round keys, conditionally transforming an input data word at each iteration (to be described more fully below). Encryption unit **204** on the other hand is intended to represent a broad range of encryption elements known in the art. Accordingly, except for the manner encryption unit **204** cooperates with ciphering round key generator **202**, encryption unit **204** will not be further described.

Also as shown, decipher function **108** is similarly constituted. Decipher function **108** includes decipher round key generation unit **206** and decryption function **208** coupled to each other as shown. Decipher round key generation unit **206** is employed to successively generate a number of deciphering round keys in real time in a pipelined and as needed manner, based off provided deciphering “master” key  $K'$  (which is the bottom  $N_k$  words of the data words of the ciphering round keys employed to generate ciphered text). Decryption function **208** is employed to incrementally decrypt or decipher ciphered text C, using the generated deciphering round keys as they are successively made available. More specifically, deciphering round key generation unit **206** generates the next deciphering round key required by decryption unit **208**, while decryption unit **208** is incrementally deciphering the ciphered text C or a partially deciphered text for another round using

the previously generated deciphering round key. In other words, deciphering round key generation unit **206** generates the first deciphering round key based off the provided deciphering “master” key K’, and provides the first generated deciphering round key to use to incrementally decipher ciphered text C. Thereafter, while

5    decryption unit **208** incrementally decipheres ciphered text C for one round, deciphering round key generation unit **206** generates the next deciphering round key. Upon completion of the first deciphering round, decryption unit **208** incrementally decipheres the partially deciphered text for another round, while deciphering round key generation unit **206** generates yet another next deciphering

10    round key. The process continues until the required number of rounds have been performed, with deciphering round key generation unit **206** generating the “last” deciphering round key (i.e. the first ciphering round key), and thereafter, decryption function **208** incrementally decipheres the partially deciphered text for one last round, reproducing the original plain text M.

15        Deciphering round key generator **206** includes in particular the same (or functionally equivalent) transformation means employed by ciphering round key generator **202** to generate the ciphering round keys. In like manner, deciphering round key generator **206** employs the transformation means in the pipelined process of the present invention for generating the deciphering round keys in a pipelined

20    manner, transforming an input data word at each iteration (also to be described more fully below). Decryption unit **208** is also intended to represent a broad range of decryption elements known in the art. Accordingly, except for the manner decryption unit **208** cooperates with deciphering round key generator **206**, decryption unit **208** will not be further described either.

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Ciphering and Deciphering Round Key Generators

**Figures 3a-3b** illustrate one embodiment each of ciphering round key generator **202** and deciphering round key generator **206** of **Figure 2** in further details, in accordance with one embodiment. As illustrated in **Fig. 3a**, for the embodiment, the ciphering “master” key is  $N_k$  data words in length ( $W_0$  through  $W_{N_k-1}$ ) **302a**, whereas each of the generated ciphering round keys is assumed to be  $N_b$  data words in length (where  $N_b$  may be less than, equal to, or greater than  $N_k$  depending on the chosen plaintext block length and master key length). Further, each of the data word  $W_i$  is  $q$  bits wide, e.g. 32 bits.

The ciphering master key  $K$  provides the top  $N_k$  words. Thus, if  $N_b = N_k$ , the first ciphering round key is the ciphering master key  $K$ ; and generation of the rest of ciphering round keys starts with the first data word of the second ciphering round key. If  $N_b > N_k$ , the first  $N_k$  data words of the first ciphering round key is provided by the ciphering master key  $K$ ; and generation of the rest of ciphering round keys starts with the  $N_{k+1}$  data word of the first ciphering round key. If  $N_b < N_k$ , the first ciphering round key is provided by the first  $N_b$  data words of the ciphering master key  $K$ ; generation of the rest of ciphering round keys starts with the  $N_{N_k-N_b+1}$  data word of the second ciphering round key (assuming  $2N_b < N_k$ , otherwise, the second ciphering round key is provided by the  $N_{b+1}$  to  $N_{2b}$  data words of the ciphering master key  $K$ , and so forth).

Thus, upon “consuming” the ciphering master key  $K$ , ciphering round key generation unit **202** in general, generates each of the subsequent ciphering round key by iteratively generating its  $N_b$  data words over  $N_b$  iterations (except for the “partial” situations described earlier). That is, the  $N_b$  data words of the  $n^{\text{th}}$  ciphering round key are generated by iteratively generating data words  $W_{(n-1)N_b}$  through  $W_{nN_b-1}$  over  $N_b$  iterations.

As illustrated, for the embodiment, ciphering round key generation unit **202** includes conditional transformation unit **303a**, and XOR function **304a**, coupled to each other as shown. Conditional transformation unit **303a** is employed to conditionally transform the last generated round key data word ( $W_{i-1}$ ), for each of the round key data word generation iterations of the ciphering round key generation process for generating a ciphering round key. XOR function **304a** is employed to generate the next round key data word ( $W_i$ ) for each of the round key data word generation iterations of the ciphering round key generation process for generating a ciphering round key. XOR function **304a** generates each next round key data word ( $W_i$ ) by performing an XOR operation on the conditionally transformed last generated round key data word ( $W_{i-1}$ ) and a predecessor round key data word of  $N_k$  data words earlier ( $W_{i-N_k}$ ), i.e. a predecessor round key data word with a predecessor distance of the length of the ciphering "master" key.

Thus, for an embodiment with  $(R+1)$  ciphering round keys, with each ciphering round key being  $N_b$  words long, a total of  $N_b(R+1)-N_k$  iterations are performed to successively generate the  $(R+1)$  ciphering round keys.

Similarly, for deciphering round key generation unit **206**, as illustrated in **Fig. 3b**, for the embodiment, the deciphering "master" key  $K'$  is  $N_k$  data words long ( $W_{N_b(R+1)-N_k}$  through  $W_{N_b(R+1)-1}$ ) **302b**, whereas each of the generated deciphering round keys is  $N_b$  data words in length. Further, each of the data word  $W_i$  is also  $q$  bits wide, e.g. 32 bits. The first  $N_k$  data words of the deciphering round keys are provided by the deciphering "master" key  $K'$ . Again, depending on whether  $N_b$  is equal to, greater than or less than  $N_k$ , generation of the data words of the deciphering round keys starts with the first data word of the second deciphering round key, the  $N_{k+1}$  data word of the first deciphering round key, or the  $N_{n_k-n_b+1}$  data word of the second ciphering round key (again assuming  $2N_b < N_k$ ). In general, upon "consuming" the data words of the deciphering master key, deciphering round

key generation unit **206** in general generates each of the subsequent deciphering round keys by iteratively generating its  $N_b$  data words over  $N_b$  iterations (except for the “partial” situations described).

As illustrated, for the embodiment, deciphering round key generation unit **206** includes conditional transformation unit **303b**, and XOR function **304b**, coupled to each other as shown. Conditional transformation unit **303b** is similarly employed to conditionally transform a predecessor round key data word of  $N_k$  data words earlier (the length of the ciphering “master” key) ( $W_{i+N_k-1}$ ), for each of the round key data word generation iterations of the deciphering round key generation process for generating a deciphering round key. XOR function **304b** is employed to generate the next round key data word ( $W_i$ ) for each of the round key data word generation iterations of the deciphering round key generation process for generating a deciphering round key. XOR function **304b** generates each next round key data word ( $W_i$ ) by performing an XOR operation on  $W'_{i+N_k-1}$  (the conditionally transformed predecessor round key data word) and  $W_{i+N_k}$  (the round key data word that  $W_{i+N_k-1}$  ‘immediately follows’). The phrase “immediately following” refers to the order of the round key data words are generated, also referred to as a “bottom to top” order of generation (see **Fig. 3b**).

Thus, for an embodiment with  $(R+1)$  deciphering round keys, with each ciphering round key being  $N_b$  words long, a total of  $N_b(R+1)-N_k$  iterations are performed to successively generate the  $(R+1)$  deciphering round keys.

Thus, it can be seen from the above description, deciphering may start as soon as the first deciphering round key is generated. Further, the amount of storage requirement needed for holding the relevant deciphering round key data words may be as little as the greater of  $N_k + 1$  or  $N_b + 1$  data words (depending on whether  $N_k$  or  $N_b$  is greater).

# Transformation Unit

**Figure 4** illustrates transformation unit **303a/303b** of ciphering/deciphering round key generator **202/206** of **Figure 3** in further detail, in accordance with one embodiment. As described earlier, transformation unit **303a/303b** conditionally transforms an input data word to be employed in the generation of the next round key data word of a ciphering/deciphering round key. As illustrated, transformation unit **303a/303b** includes conditional passthru circuitry **306a** and **306b**, inverse lookup table **308a** and **308b**, substitution boxes **309a** and **309b**, rotational shift register **307**, XOR function **310**, and selector **312**, coupled to each other as shown.

Conditional passthru circuitry **306a-306b** conditionally routes an input data word ( $W_{i-1}$  in the case of ciphering, and  $W_{i+N_k-1}$  in the case of deciphering) to one of three transformation paths, to be transformed zero or more times, depending on at least the multiplicity between the iteration index  $i$  and the deciphering master key length ( $N_k$ ), to be described in more detail below.

Rotational shift register **307** is part of the transformation path that transforms the input data word multiple times. Specifically, it is employed on the “yes” path of passthru circuitry **306a** to rotate the input data word in a predetermined direction for a predetermined number of bits. For the illustrated embodiment, the predetermined direction is rotation to the “left” (towards the MSB) and the predetermined number of bits is 8. In alternate embodiments, other quantities of rotation as well as rotation to the right (towards the LSB) may be practiced instead

For the illustrated embodiment, the inverse lookup circuitry and substitution box pairs **308a** and **309a**, and **308b** and **309b**, are disposed on two transform paths providing one and multiple transformations to the input data word (on a byte basis) respectively. Each inverse lookup circuitry **308a/308b** looks up the inverse of a byte of the input data word. In one embodiment, the inverse values are pre-computed e.g. by computing the multiplicative inverse of  $GF(2^8)$  modulo the binary polynomial

of 0x11B (where 0x00(zero) is defined as its own inverse). In alternate embodiments, the inverse values may be computed in real time. Each substitution box **309a/309b** is an 8x8 substitution box containing a number of predetermined substitution values to be applied to each byte of an input data word. The manner in which the substitution values may be determined is described in more detail below.

When routed along the “yes” path of passthru circuitry **306a**, the input data word, upon rotation (using rotational shift unit **307**), is transformed using the inverse lookup and substitution box pair **308a** and **309a**. As alluded to earlier, the transformation is applied on a byte by byte basis. That is, the transformation is applied to each byte independently. The twice transformed input data word is further transformed by XOR function **310**, performing an XOR operation on the twice transformed input data word and a computational constant. The computational constant is looked up from a look up table (not shown) having values ( $z^{j-1}$ , 00, 00, 00), where  $j$  is the look up index, and equals to the floor value of dividing the iteration index  $i$  by  $N_k$ . Thereafter, the thrice transformed data word is provided to selector **312** for selection, which selects the thrice transformed data word if the transformations provided by the “yes” path of passthru circuitry **306a** is to be applied.

When routed along the “yes” path of passthru circuitry **306b** (and “no” path of passthru circuitry **306a**), the input data word is transformed using the inverse lookup and substitution box pair **308b** and **309b** (on a byte by byte basis as earlier described). The transformed input data word is provided to selector **312** for selection, which selects the particular transformed data word if the transformation provided by the “yes” path of passthru circuitry **306b** (and “no” path of passthru circuitry **306a**) is to be applied.

When routed along the “no” path of passthru circuitry **306b** (and “no” path of passthru circuitry **306a**), the input data word is provided to selector **312** for selection

(without transformation), which selects the particular untransformed data word if no transformation handling provided by the “no” path of passthru circuitry **306b** (and no path of passthru circuitry **306a**) is to be followed.

Each of these elements, conditional passthru circuitry **306a-306b**, rotational shift register **307**, inverse lookup circuitries **308a-308b**, substitution boxes **309a-309b**, XOR function **310**, and selector **312** may be formed using any individual or combinations of combinatorial logic and/or storage elements known in the art. Further, other manners of transformation, in particular, non-byte basis transformation may be employed instead.

For the illustrated embodiment, the no transformation handling provided by the “no” paths of passthru circuitry **306a-306b** is followed if the iteration index  $i$  is not a multiple of  $N_k$  or  $N_k$  is not greater than 6 or if  $N_k$  is greater than 6 but the value of iteration index  $i$  minus 4 is not a multiple of  $N_k$ . If the iteration index  $i$  is a multiple of  $N_k$ , the transformations provided by the “yes” paths of passthru circuitry **306a** are applied. On the other hand, if the iteration index  $i$  is not a multiple of  $N_k$  but  $N_k$  is greater than 6, and the value of the iteration index  $i$  minus 4 is a multiple of  $N_k$ , the transformation provided by the “yes” path of passthru circuitry **306b** (and “no” path of passthru circuitry **306b**) is applied.

#### Substitution Values Computation and Example Data Structure

As alluded to earlier, for the illustrated embodiment, each substitution box is 8x8 in size to be applied to each byte of a data word. In one embodiment, the substitution byte values of the substitution box may be determined as follows. Let  $x_0x_1\dots x_7$  and  $y_0y_1\dots y_7$  represent the corresponding 8 bits of the  $x$  input and  $y$  output values of the 8x8 embodiment. That is, the  $x$  input values are the selected byte outputs of the “inverse” lookup circuitry **308a/308b** based on the input data word. Then  $x$  and  $y$



can be said to have affine relation of  $y = Ax + b$ , where operations are computed mod 2, and where A and b are given by

$$A = \begin{bmatrix} 10001111 \\ 11000111 \\ 11100011 \\ 11110001 \\ 11111000 \\ 01111100 \\ 00111110 \\ 00011111 \end{bmatrix} \quad b = \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \\ 0 \\ 1 \\ 1 \\ 0 \end{bmatrix}$$

**Figure 5** illustrates a look up table suitable for use to implement the look up tables for storing the Rconst values of **Figures 3a-3b**. As illustrated, the desired iteration index dependent computational values, for efficient of operation, may be pre-computed and stored into example lookup table **500** comprising at least two columns **502** and **504**. Column **502** is employed to store the computed input value, which as described earlier is equal to the floor value of dividing the iteration index  $i$  by  $N_k$  (the number of data words in the ciphering "master" key). Column **504** is employed to store the output values  $(z^{i-1}, 00, 00, 00)$ .  $z^{i-1}$  is an element of  $GF(2^8)$ .

In one alternate embodiment (where transformation is performed on a byte by byte basis),  $z$  is set to 2, and Rconst is dynamically generated instead. The left most byte of Rconst is generated by left shifting the constant 1 (the other bytes of Rconst are zero). That is, the left most byte of the  $j$ th constant is given by  $(1 \ll j)$ , where the symbols " $\ll$ " stand for left shifting, and  $(1 \ll j)$  means left shift by  $j$  bits. (Accordingly, in this alternate embodiment, the lookup table illustrated in **Fig. 5** is not needed.)

Example Application

**Figure 6** illustrates an example application of the present invention. As illustrated, data routing device **602** comprising receive interface **604** and transmit interface **612** is advantageously provided with a number of decryption functions **606** and a number of encryption functions **610**. Additionally, data routing device **602** may also include a number other function units **608**. Decryption functions **606** and encryption functions **610** are provided to perform decryption and encryption for a number of network traffic flows, one each for a network traffic flow. More importantly, decryption functions **606** and encryption functions **610** are incorporated with the teachings of the present invention, enabling them to advantageously generate the deciphering/ciphering round keys in a pipelined and as needed manner. The deciphering master keys ( $K'$ ) of the different decryption functions **606** for the different network traffic flows may be the same, or different, or some are the same, while others are different. Likewise, the ciphering master keys ( $K$ ) of the different encryption functions **610** for the different network traffic flows may be the same, or different, or some are the same, while others are different.

Typically, the  $K$ 's and  $K$ s are provided to data routing device **602** e.g. by a network administrator. Alternatively, the  $K$ 's may be exchanged between data routing device **602** and another party who wants to engage in secured communication with data routing device **602**. The provision may e.g. be made over secured channels (not shown). Of course, the  $K$ 's are pre-generated from their corresponding  $K$ s.

As described earlier, each of decryption functions **606** and encryption functions **610** may start decryption and encryption of the corresponding network traffic flow as soon as the first deciphering or ciphering round key is available (with or without having to be at least partially generated, as the case may be depending on the relative size of  $N_b$  and  $N_k$  as described earlier). Further, the amount of

storage requirement for provisioning data routing device 602 to be able to handle the decryption and encryption of multiple network traffic flows at the same time is substantially reduced under the present invention. As a result of the storage requirement savings, data routing device 602 may be advantageously disposed on a single integrated circuit. Thus, together with the "fast start", data routing device 602 is able to handle high speed line rate data decryption and encryption for multiple data flows at the same time. In one embodiment, data routing device 602 is an IC component for routing packets transmitted over an optical medium onto an electrical medium at very high speed.

The advantages of data routing device 602 is most evident when the K's can be reused multiple times, such as in bulk encryption applications (e.g. SSH tools such as ssh and scp, or Secure Sockets Layer (SSL) services for secure web browser sessions) where many blocks of data need to be encrypted using the same key, sent securely, then decrypted.

#### Conclusion and Epilogue

Thus, it can be seen from the above descriptions, a novel method and apparatus for deciphering ciphered text, in particular, having the required deciphering round keys generated in a pipelined manner on an as needed basis, has been described. While the present invention has been described in terms of the above described embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims. Thus, the description is to be regarded as illustrative instead of restrictive on the present invention.